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Design and Development of Low Frequency Wave Based Fire Extinguisher

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Abstract: ***The project titled Designing of Fire Extinguisher Based on Sound Waves is associated with new technique of fire extinguisher. Deals with the firefighting operations with a quick response time. The purpose of sound wave extinguisher is to find out the range of frequency within which fire can be extinguished. It helps the fire fighter to fight the fire at early stage. Fire can be extinguished between 40Hz to 60Hz and the sound wave can extinguish the fire of all types of flames. The fire suppression needs to be done at the incipient stage where the heat and flame produced by the fire is at the minimum point. The expected outcome of the project will be, to counter the fire at its initial stage for better human safety and protection.***
Keywords: Fire, Flame, Fire Extinguishers ,Chemical extinguisher, Residue, Sound Waves, Sound Wave Fire Extinguisher, Fire extinguishing effect, Dousing Fire

I. INTRODUCTION

Fire extinguishers are essential devices used to control and suppress fires, especially at their early stages, ensuring safety and preventing major damage. Conventional extinguishers use water, foam, or chemicals, which may leave residue or harm the environment. To overcome these limitations, this project introduces an innovative fire suppression technique using sound waves.

The Sound Wave Fire Extinguisher operates in the low-frequency range of 40–60 Hz, where sound waves disrupt the combustion process by creating pressure variations that reduce the oxygen supply to the flame. This results in extinguishing the fire without the use of any chemicals or liquids. The system is designed to act quickly during the incipient stage of fire, improving response time and safety.

This method is eco-friendly, easy to operate, and leaves no residue, making it a promising alternative to traditional fire extinguishing systems.

II. METHODOLOGY

Fire extinguisher is an equipment primarily designed for fire fighting operations. Extinguishers are generally used by fire departments and also to fight the fire at its growth stage. The primary purpose of fire extinguisher is its easy operation, easy to handle, and leaves no residue after usage, and doesn't harm the environment. A sound wave extinguisher will extinguish the flame of all types and the frequency range can be measured between 40Hz to 60Hz. Further the waves can

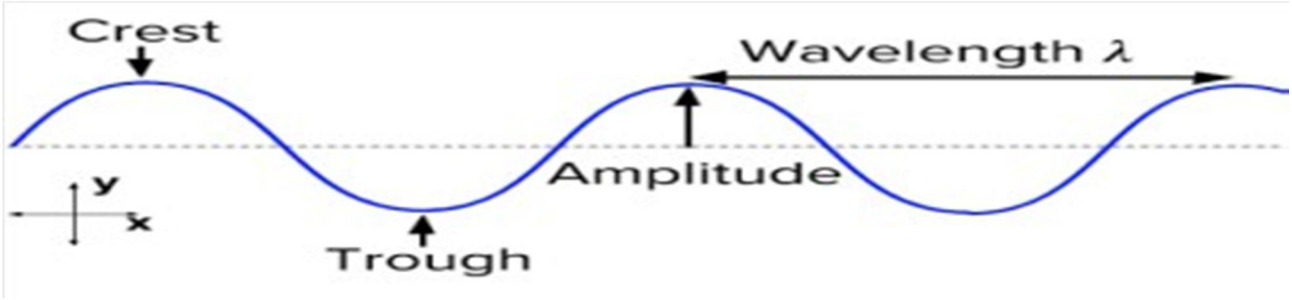


Figure 1.1: Longitudinal Waves

be classified into two groups which are mentioned as under:

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1. In the figure 1.1, **the longitudinal wave** also known as compression wave which provides compression and rarefaction when moving in the same direction or opposite. The displacement of the medium can be vice- versa.
2. In the figure 1.2, **the transverse wave** known as moving wave and has number of oscillations occurring perpendicular from the energy where it is transferred. One of the best reasons is light. Medium of displacement is perpendicular to the wave propagation of direction.

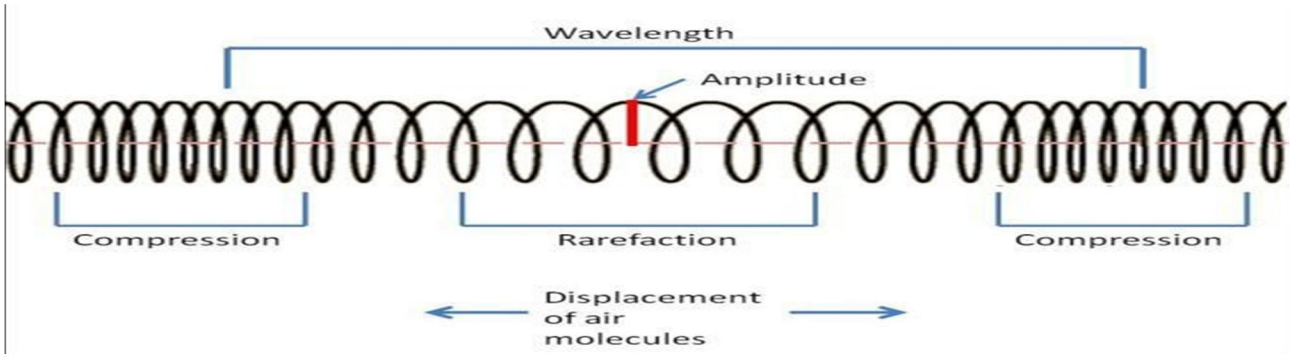


Figure 1.2: Transverse Wave

A. Fire

The figure 1.3, the three important elements that forms the 'Fire Triangle' i.e. Heat, Fuel and Oxygen. As fire is primarily an exothermic chemical reaction i.e. the rapid oxidation of the available fuel in the presence of heat source and gives by-products such as: - heat and light energy sensation and removing one or more of these three elements will extinguish the flame/fire.

B. Flame

A flame is the visible, gaseous part of a fire. It is caused by a highly exothermic reaction taking place



Figure 1.3: Fire Triangle

C. Fire Extinguishing Methods

The principle of fire extinction states that a fire will be doused if one of the three elements is removed, and this can be done using three different approaches. They are: - Cooling (Cooling the Burning Material)
Starving (Removing Fuel from the Fire) Smothering (Excluding Oxygen from the Fire).

D. Types of Fire:

Class A - Fire which includes solid materials like wood, paper, plastic, rubber etc.
Class B - Fire containing flammable liquids.
Class C - Fire involves gaseous substances.
Class D – contains combustible metals like aluminium, zinc, sodium, potassium etc.

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III. PROPOSED SYSTEM

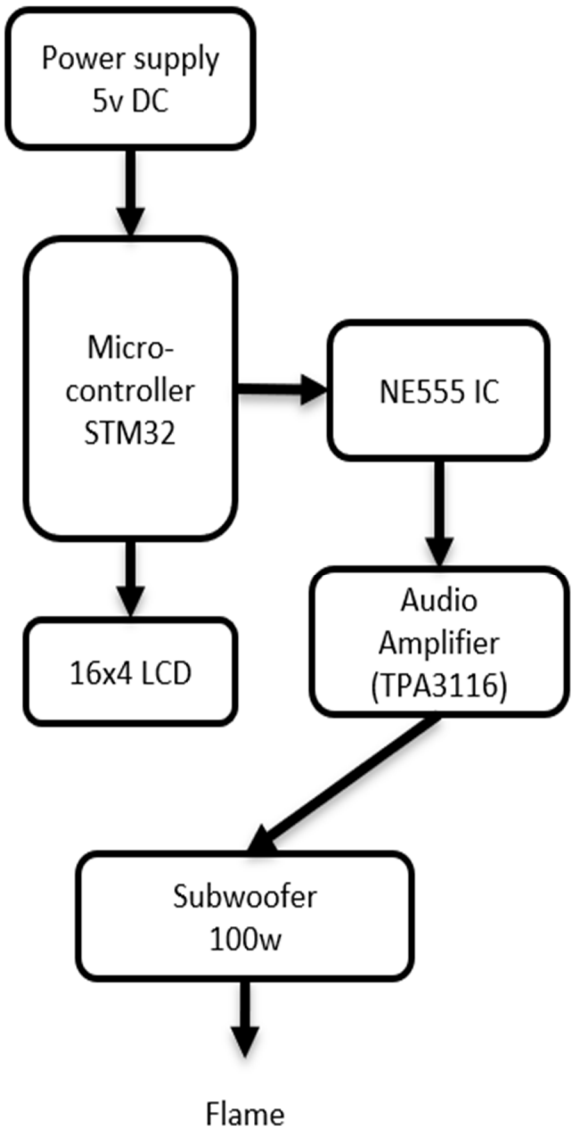


Figure: 3.1 Block Diagram

In the figure 3.1, the block diagram represents the working of a sound wave-based fire extinguisher system. The system is powered by a 5V DC power supply, which provides the necessary energy to the microcontroller (STM32) and other connected components.
The STM32 microcontroller acts as the main control unit of the system. It manages the overall operation and displays system parameters on the 16×4 LCD for user monitoring. The microcontroller also controls the signal generation process.
The amplified signal is delivered to a high-power 100W subwoofer, which converts the electrical signals into strong low-frequency sound waves. These sound waves are directed towards the flame.

IV. IMPLEMENTATION AND WORKING

An NE555 IC is used to generate low-frequency signals in the required range of 40–60 Hz. These signals are then fed into the audio amplifier (TPA3116), which amplifies the signal to a higher power level suitable for driving the speaker.
The produced acoustic waves create pressure variations that disturb the combustion process by reducing the oxygen supply around the flame, thereby extinguishing it effectively

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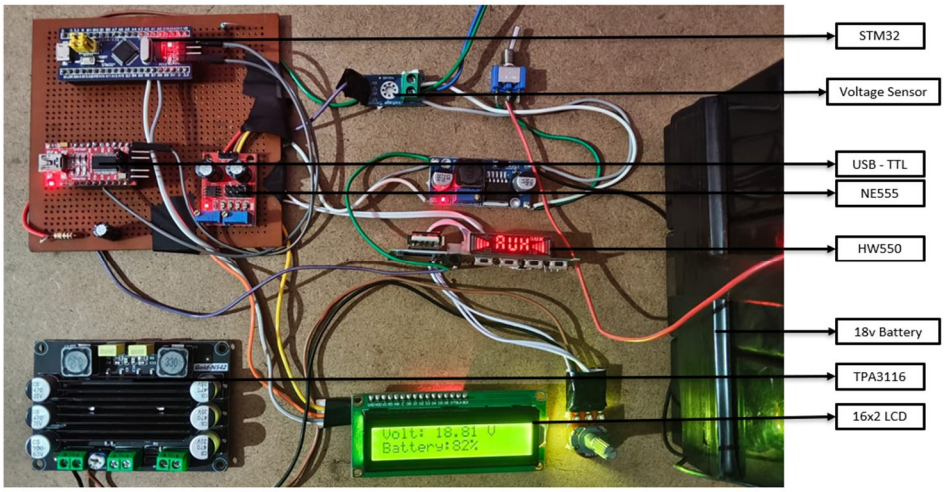


Figure: 4.1 Hardware Setup

In the figure 4.1, the hardware implementation of the sound wave-based fire extinguisher system is shown. The system is built using an STM32 microcontroller as the main control unit, which is mounted on a development board and connected to various peripheral modules.

An 18V battery serves as the primary power source for the system. A voltage sensor module is used to monitor the battery voltage, and the measured value is processed by the STM32. The real-time voltage and battery percentage are displayed on a 16×2 LCD, providing continuous system status to the user.

A USB-to-TTL module is included for programming and serial communication with the microcontroller. The NE555 timer IC is used to generate low-frequency signals required for fire suppression. These signals are then passed through an HW550 module for signal conditioning and control.

The conditioned signal is fed into the TPA3116 audio amplifier, which amplifies the signal to a high power level. The amplified output is then delivered to a subwoofer, which produces strong low-frequency sound waves.

These sound waves are directed towards the flame, where they create pressure disturbances that reduce the oxygen supply around the fire, thereby extinguishing it. This setup demonstrates a practical implementation of an eco-friendly and efficient fire suppression system using sound waves on hand, if properly not handled.

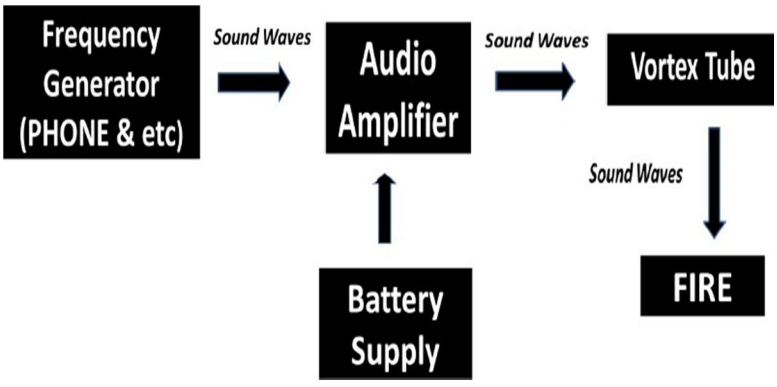


Figure 4.2: Work Flow

In the figure 4.2, this concept teaches the physics, engineering and electronics approach so as to suppress a flame. Firstly, to get the knowledge of acoustical properties of sound waves which are longitudinal waves that moves backward and forward creating vibrating motion, as a result of which molecules moves away from the flame. Another is Ideal Gas which states that (PV=nRT) helps in suppressing a flame. So when pressure is exerted at the flame source it will get decreased and temperature will also get decreased of the flame.

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A USB-to-TTL module is included for programming and serial communication with the microcontroller. The NE555 timer IC is used to generate low-frequency signals required for fire suppression. These signals are then passed through an HW550 module for signal conditioning and control flame.

V. RESULT ANALYSIS AND DISCUSSION

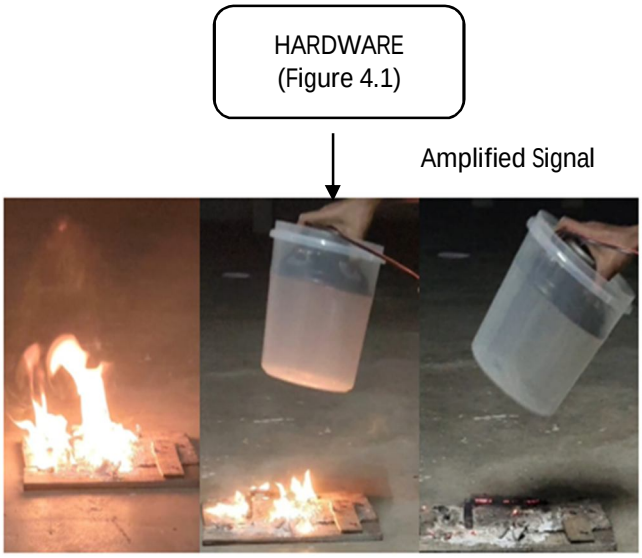


Figure 5.1: Testing of Sound Wave Fire Extinguisher

In the figure 5.1 illustrates the experimental results of the sound wave-based fire extinguisher system. In the initial stage, a stable flame is generated on a surface, representing a typical small-scale fire. As the system is activated (figure 4.1), low-frequency sound waves are directed towards the flame using the subwoofer setup.

In the second stage, the effect of the sound waves becomes visible as the flame starts to flicker and reduce in intensity. This occurs due to the pressure variations created by the sound waves, which disturb the combustion process and reduce the availability of oxygen around the flame.

In the final stage, the flame is completely extinguished without the use of water, foam, or any chemical agents. The result clearly demonstrates that low-frequency acoustic waves can effectively suppress fire at its early stage. This method proves to be eco-friendly, residue-free, and efficient for fire control applications.

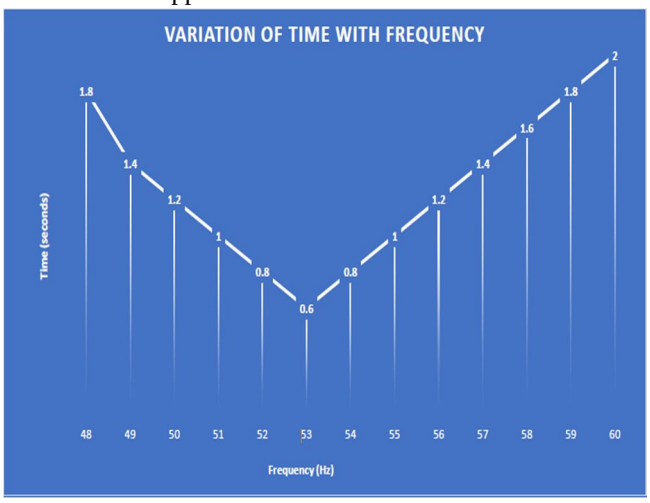


Figure 5.2: Frequency Graph of the Experiment Performed

Testing of the Portable Sound Wave Fire Extinguisher on Liquid Fire.

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The vortex tube necessary to be included in the construction of this experiment has the following dimensions for optimization of extinguishing effect: Length is 300 mm and outlet diameter is 100 mm. The optimal frequency is found to be between 51-55 Hz.

VI. CONCLUSION

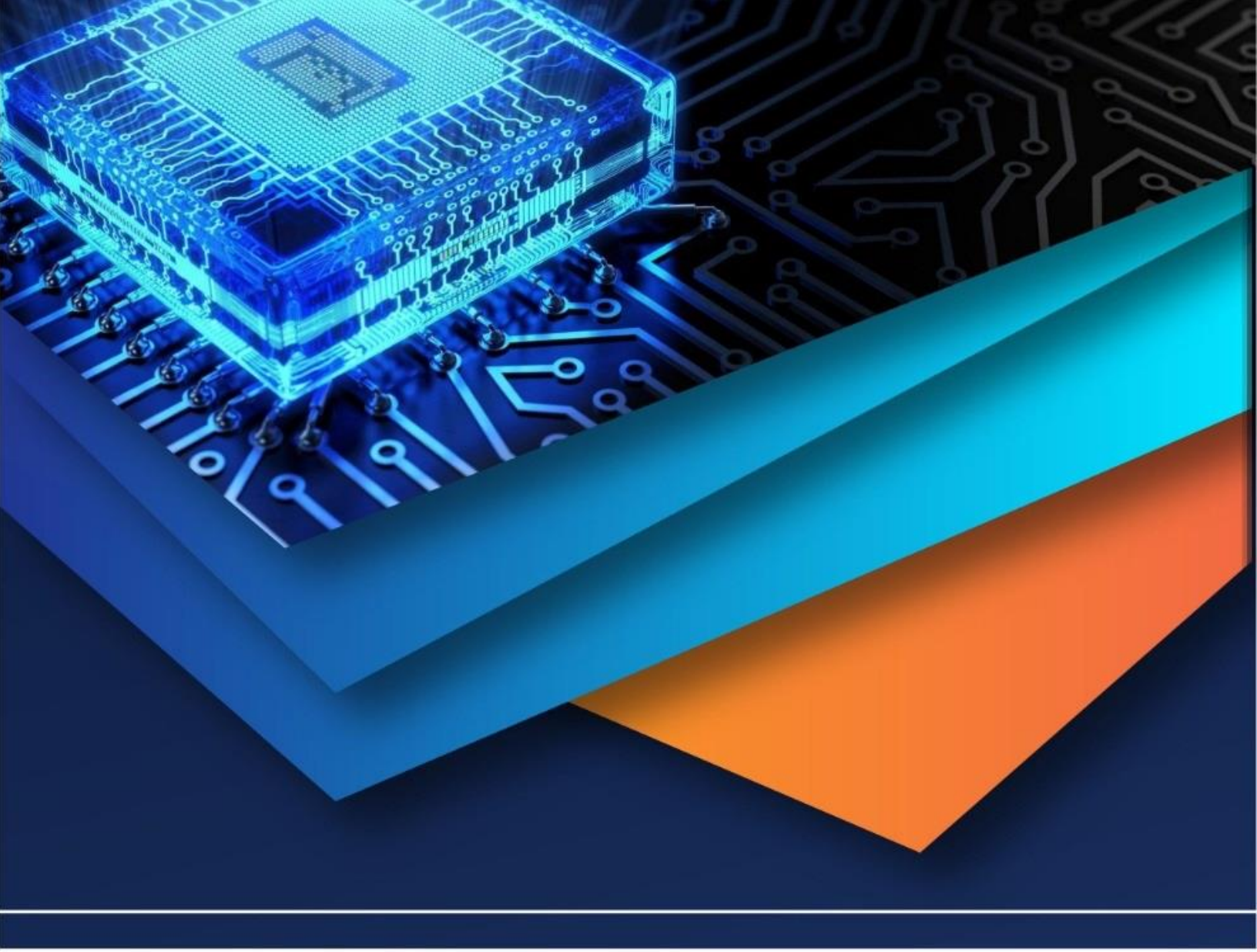
Overall, the design and development of the sound wave fire extinguisher have been carried out successfully, demonstrating the effectiveness of using acoustic energy as an alternative fire suppression method. The system was carefully designed, assembled, and tested, and all the intended functions of the extinguisher operated as expected. The generated low-frequency sound waves were able to interact with the flame by disturbing the combustion process, primarily by displacing oxygen around the fire and reducing the intensity of the flame.

Throughout the experimentation process, it was observed that the extinguisher responded efficiently under controlled conditions, successfully suppressing small flames. The integration of components such as the signal generator, amplifier, and speaker system contributed to the proper generation and direction of sound waves toward the fire source. The results obtained validate the concept that sound waves, when produced at appropriate frequencies and intensities, can effectively extinguish flames without the need for water or chemical agents.

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